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(54) **Linear induction motor door operator**

(57) An elevator car door system for opening and closing elevator car doors (12) in an elevator car includes a high performance linear induction motor having a pair of movable motor primaries (16) attached to a respective door hanger (14) of each door, and a stationary motor secondary (18) attached to a header bracket (20) which is secured to the elevator car. Each motor primary includes a primary winding (24) and a backiron (26) spaced apart by a plurality of spacers (28) that establish a magnetic gap (40) therebetween. The motor secondary fits between the primary winding and the backiron as the moving motor primaries travel across the motor secondary, generating thrust.

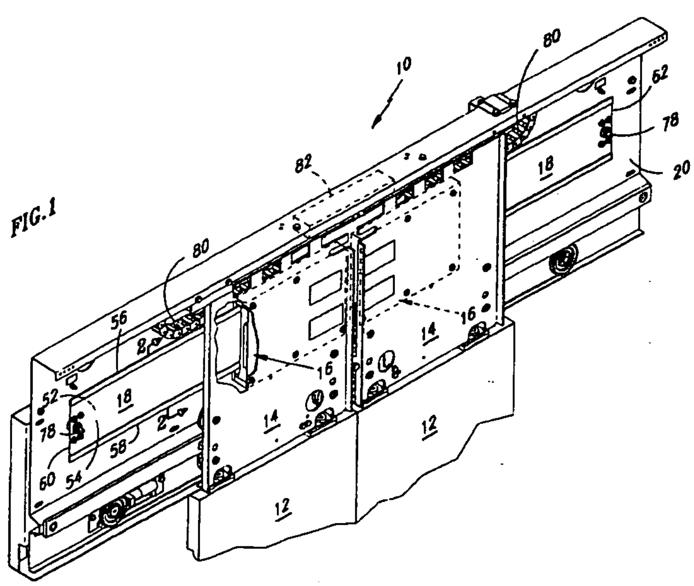

FIG.1

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Description

The present invention relates to elevator systems and, more particularly, to high performance linear induction motors driving elevator car doors thereof.

Many considerations play a role in the selection of a system to drive elevator car doors in an elevator. One major constraint in elevators is space. The first space limitation is the length of the door system. The door operating system has to fit within the hoistway and thus cannot exceed the width of the elevator car, which is frequently referred to as the elevator envelope. The second space limitation is the thickness of the door operating system. The door operating system has to be sufficiently narrow as not to interfere with the hoistway as the elevator car travels up and down the hoistway. If the door system is too large and cannot fit between the elevator car and the hoistway, the door system will encroach on the elevator car space. An alternative to encroaching on elevator car space is to mount the door operating system on top of the elevator car. However, such a solution would invite other problems such as an increase in door rocking, restriction of overhead running clearance, and limited access to the car top. Therefore, the door operating system should not enlarge the car door envelope and should be sufficiently narrow as not to interfere with the hoistway.

Another major consideration in selecting the elevator car door operating system is the cost of the system and the cost of maintaining and servicing the system. The size of the motor determines the cost of each unit. Also, the tight tolerances required for some motor configurations increase the cost by demanding expensive precision manufacturing.

An additional constraint in the selection of the door operating system is weight. Since the door operating system is mounted directly on the elevator car and travels therewith, the door operating system should not be excessively heavy.

Once the door operating system meets the space, cost, and weight limitations, it must have a certain level of performance. The opening and closing of the elevator car doors must be simultaneous, smooth, and quiet.

In conventional elevator systems, elevator car doors are selectively opened and closed by a rotary electric motor driving a mechanical assembly, which typically includes a plurality of moving parts such as gear boxes, a set of drive arms, linkages and cams. The major drawback of the existing elevator car door system is that it is susceptible to misalignments and requires frequent adjustments that result in high maintenance costs. Also, the misalignments degrade the performance of the system such that door opening and closing functions are not consistently smooth.

An alternative to the existing mechanical door system is a linear motor driven door system. Although a number of patents have disclosed the use of linear motors on doors, use of linear motors in door systems in general, and in elevator car door systems specifically, has been very limited. Most of the existing proposals have significant shortcomings and are not practical because they violate either space, cost, or weight constraints, or a combination thereof.

For example, U.S. Patent No. 1,881,016 shows a door system driven by a linear induction motor. The patent teaches a motor secondary attached to one door and a motor primary attached to a second door. The major shortcoming of the disclosed configuration is that the excessively long motor secondary is free hanging and cannot be supported. Additionally, the unsupported motor secondary may buckle when compressed during the door opening function. Thus, the Rose patent does not provide a practical alternative to the existing door systems.

U.S. Patent No. 1,881,014 shows a door system with a motor secondary attached to a door and moving therewith, and a stationary motor primary. One major drawback of the disclosed configuration is that since the moving motor secondary overhangs the door on both sides, the door opening envelope is significantly enlarged. Therefore, this disclosure also does not represent a practical solution for modern elevator door systems.

U.S. Patent No. 5,172,518 discloses an apparatus for doors using a linear motor. The patent shows two U-shaped motor primaries attached to a single door and a T-shaped motor secondary. One major reason for the disclosed configuration not being suitable for modern elevators is the thickness of the motors. Another major reason is that the open structural portion of the U-shaped motor primary may incur buckling from inherently high attractive forces.

Therefore, none of the existing proposals provides a practical alternative to current mechanically driven elevator door system.

Viewed from one aspect the present invention provides an elevator car door operating system for opening and closing an elevator car door in an elevator system, including a door hanger suspending said elevator car door therefrom, said door hanger being movably secured to a header attached to an elevator car, said system comprising:

a motor primary unit fixedly attached to said door hanger, said motor primary unit including a primary winding spaced apart from a backiron by means of a plurality of spacers and defining a constant magnetic gap therebetween; and
a motor secondary extending the length of the door travel of said elevator car door and fitting between said primary winding and said backiron, said motor secondary having first and second vertical ends and top and bottom longitudinal edges.

One advantage of the present invention, at least in its preferred embodiments, is that it provides a practical

alternative to conventional mechanical linkages, thereby increasing the reliability of the door system, improving performance and reducing maintenance costs. Another advantage is that it meets space and weight constraints. By placing a motor primary on each door hanger and by fixing the motor secondary to the car frame, the space envelope required for the door system is reduced. The door system may also be made sufficiently thin to fit on the elevator car without encroaching on the elevator car space.

An embodiment of the invention will now be described by way of example and with reference to the accompanying drawings, in which:-

FIG. 1 is a cut-away schematic perspective view of an elevator door system driven by a linear induction motor, according to the present invention; and
FIG. 2 is a schematic cross-sectional view of the linear induction motor of FIG. 1, taken along the line 2-2.

Referring to FIG. 1, an elevator car door operating system 10 for opening and closing a pair of elevator car doors 12 that are suspended from a pair of door hangers 14 includes a pair of moving motor primary subassemblies 16 fixedly attached to the respective door hangers 14, and a stationary motor secondary 18 attached to a header bracket 20 secured to a car frame (not shown).

Referring to FIG. 2, each of the moving motor subassemblies 16 includes a primary winding 24 and a backiron 26 spaced apart from the primary winding 24 by a plurality of motor spacers 28. The primary winding 24 includes a primary iron unit 30 with winding 32 wrapped about it and a primary surface 34 facing the backiron 26. The backiron 26 includes an iron plate having a backiron surface 38 facing the primary winding 24. A magnetic air gap 40 is defined between the primary surface 34 and the backiron surface 38.

Each spacer 28 includes a spacer bar 42 framed by a spacer head 44 on each end thereof. Each spacer head 44 fixes spacing between the primary winding 24 and the backiron 26. The spacer bar 42 of each spacer 28 has a spacer surface 46 facing the backiron 26. The spacer bar 42 is adapted to clamp the primary winding 24 against the door hanger 14. Each moving motor primary subassembly 16 is fixedly attached to its door hanger 14 by means of a plurality of bolts 48 passing through the backiron and the motor spacer heads 44. The length of each moving motor primary 16 does not exceed the width of each door hanger 14.

The stationary motor secondary 18 extends the length of the elevator car door travel and fits between the backiron 26 and the primary winding 24 as the moving motor primaries 16 travel across, opening and closing the doors 12. The motor secondary 18 comprises a substantially flat plate having a first surface 52 and a second surface 54 bounded by top and bottom longitudinal edges 56,58 extending the length of the motor secondary 18 and by first and second vertical ends 60,62, as best seen in FIG. 1. Each longitudinal edge 56, 58 is bent over to form a lip 64 along the length of the second surface 54 of the motor secondary 18. A secondary guide 66 is placed over each longitudinal edge 56,58 of the motor secondary 18. The secondary guide 66 has an elongate U-shaped body, the internal width of which is equal to the thickness of the doubled over longitudinal edge 56,58 of the motor secondary. The U-shaped body includes a first leg 70 and a second leg 72 with the second leg having length substantially equal to the length of the bent over lip 64. The second leg 72 also includes a tab 74 integrally formed at the end thereof. A secondary guide 66 is snapped on each longitudinal edge 56,58 of the motor secondary with the tab 74 fitting over the bent over lip 64 to secure the secondary guide 66 to the motor secondary 18.

The outside surface of the first leg 70 of the secondary guide 66 comes in contact with the backiron surface 38. The outside surface of the second leg 72 of the secondary guide 66 comes in contact with the spacer bar surface 46. Each spacer 28 is dimensioned so that a running clearance is defined between the second surface 54 of the motor secondary 18 and the primary surface 34. The spacer bar surface 46 is indented from the plane of the primary surface 34 of the primary winding 24 to compensate for the thickness of the lip 64 of the motor secondary 18. Therefore, the running clearance between the backiron surface 38 and first surface 52 of the motor secondary 18 and between the primary surface 34 and the second surface 54 of the motor secondary 18 is established by the secondary guides 66 and equals the thickness of the first and second legs 70,72 of the secondary guide 66, respectively.

The motor secondary 18 is movably attached to the header bracket 20 at the two ends 60,62 thereof, as best seen in FIG. 1. The motor secondary is mounted on the header bracket 20 on a standoff 78 to allow the backiron 26 to travel between the header bracket 20 and the motor secondary 18. The standoff 78 also includes a swivel joint allowing the motor secondary 18 to move in and out of plane and to rotate about the joint 78.

The door system 10 also includes a pair of moving flexible cables 80 and a termination box 82 attached to the header bracket 20, as best seen in FIG. 1. Each cable 80 attaches to the termination box 82 at one end thereof and to the respective motor primaries 16 at the other end thereof.

In operation, the moving flexible cables 80 transmit energy from the termination box 82 to the respective motor primaries 16. As each motor primary 16 travels across the motor secondary 18, the end of the flexible cable attached to the motor primary travels therewith. The winding 30 of the motor primary 16 is energized and produces a magnetic field across the primary surface 34 of the motor primary. The magnetic field induces current in the motor secondary 18 and also travels through the backiron 26. Magnetic forces generated within the

motor secondary 18 react with the magnetic field created by the motor primary 16 and result in a thrust force from the motor primary 16 to the motor secondary 18, thereby opening and closing the elevator car doors 12.

The present embodiment ensures that the magnetic air gap 40 is constant and relatively small throughout operation of the door system. The magnetic air gap remains constant during operation of the door system because first, the configuration of the present embodiment has the backiron 26 travelling with the primary winding 24. Second, the motor spacers 28 ensure that the magnetic air gap does not vary as the backiron 26 and primary winding 24 travel across the motor secondary 18. The size of the magnetic air gap is determined by the thickness of the motor secondary 18 and the running clearances. The magnetic air gap 40 is minimal in the configuration of the present embodiment because the motor secondary is a very thin plate of copper and because the running clearances between the motor secondary 18 and motor primary 16 are minimal. A small and constant magnetic air gap ensures high efficiency and consistency in performance of the motor. For example, in the present embodiment the thickness of the copper plate of the motor secondary is approximately one and a half millimeters (1.5 mm).

The running clearances between the backiron 26 and the motor secondary 18 and between the motor secondary 18 and the primary winding 24 are established by the secondary guides 66 and are maintained constant and small without causing friction and wear between the moving and stationary motors. Small and constant running clearances are achieved without requiring costly precision machining for high tolerances and ensure a small and constant magnetic gap. For example, the running clearance on each side of the motor secondary is approximately one millimeter (1 mm).

When the doors 12 open and close, the swivel joints 78 allow the motor secondary 18 to move in many dimensions and compensate for possible misalignment or impact of the doors 12. If a door 12 is either misaligned or impacted, such misalignments and impacts are transmitted to door hangers 14 and also to the motor primaries 16 that are fixedly attached to the door hangers 14. When the motor primary 16 moves in and out of plane or is slightly rotated, the stationary motor secondary 18 also moves about the swivel joints 78 so that the running clearances are maintained constant.

A major advantage of the present embodiment is that it eliminates the need for a rotary motor and mechanical linkages, thereby significantly reducing maintenance costs associated with misalignment and periodic readjustments of the linkages. A linear induction motor of the present embodiment also provides superior and much smoother operation of the doors.

The primary advantage of the present embodiment is that it provides not only a high performance, high efficiency linear induction motor door opening system for elevator cars, but also a practical and economical one. Although the prior art shows some configurations of linear motors on doors in general, none of those prior art references, separately or in combination, provide a practical and economical solution to conventional mechanical linkage door systems.

An additional advantage of the present embodiment over the prior art is that is does not violate the space constraints. First, the configuration of the present embodiment does not enlarge the space envelope required for the door system. Second, this particular configuration allows the motor to be sufficiently thin to be placed and used for door systems without encroaching on the elevator car space.

Another advantage of the present embodiment over the prior art is its cost effectiveness. Use of linear induction motors, rather than permanent magnet motors, makes the door system affordable. Also, use of a small motor primary, having a single winding unit, maintains a reasonable price for the door system. Both of these attributes of the present embodiment also reduce the weight of the system.

While the present invention has been illustrated and described with respect to a particular embodiment thereof, various modifications may be made. For example, although the illustrated embodiment depicts a center opening-by-parting door system, a single slide door system is possible using a single motor primary. Also, the embodiment describes the motor secondary as a thin conductive plate of copper. Other conductive metals can be also used for fabricating the motor secondary. Additionally, the backiron of the motor primary can be replaced by another winding.

Claims

1. An elevator car door operating system for opening and closing an elevator car door (12) in an elevator system, including a door hanger (14) suspending said elevator car door therefrom, said door hanger being movably secured to a header (20) attached to an elevator car, said system comprising:

   a motor primary unit (16) fixedly attached to said door hanger, said motor primary unit including a primary winding (24) spaced apart from a backiron (26) by means of a plurality of spacers (28) and defining a constant magnetic gap (40) therebetween; and
   a motor secondary (18) extending the length of the door travel of said elevator car door and fitting between said primary winding and said backiron, said motor secondary having first and second vertical ends (60,62) and top and bottom longitudinal edges (56,58).

2. A system according to claim 1, wherein said motor secondary (18) is made of a conductive metal.

3. A system according to claim 2, wherein said conductive metal is copper.

4. A system according to any of claims 1 to 3, wherein said motor secondary (18) is movably attached to said header (20) at its said first and said second vertical ends (60,62).

5. An elevator car door operating system for opening and closing a first elevator car door (12) and a second elevator car door (12) in an elevator system, including a first door hanger (14) and a second door hanger (14) suspending said first and said second elevator car doors therefrom, said first and said second door hangers being movably mounted on a header (20) attached to an elevator car, said system comprising:

a first motor primary unit (16) fixedly attache to said first door hanger, said first motor primary unit including a first primary winding (24) spaced apart from a first backiron (26) by means of a first plurality of spacers (28);
a second motor primary unit (16) fixedly attached to said second door hanger, said second motor primary unit including a second primary winding (24) spaced apart from a second backiron (26) by means of a second plurality of spacers (28); and
a motor secondary (18) comprising a substantially flat plate extending the length of the door travel of said first and said second elevator car doors and fitting between said first primary winding and said first backiron and between said second primary winding and said second backiron.

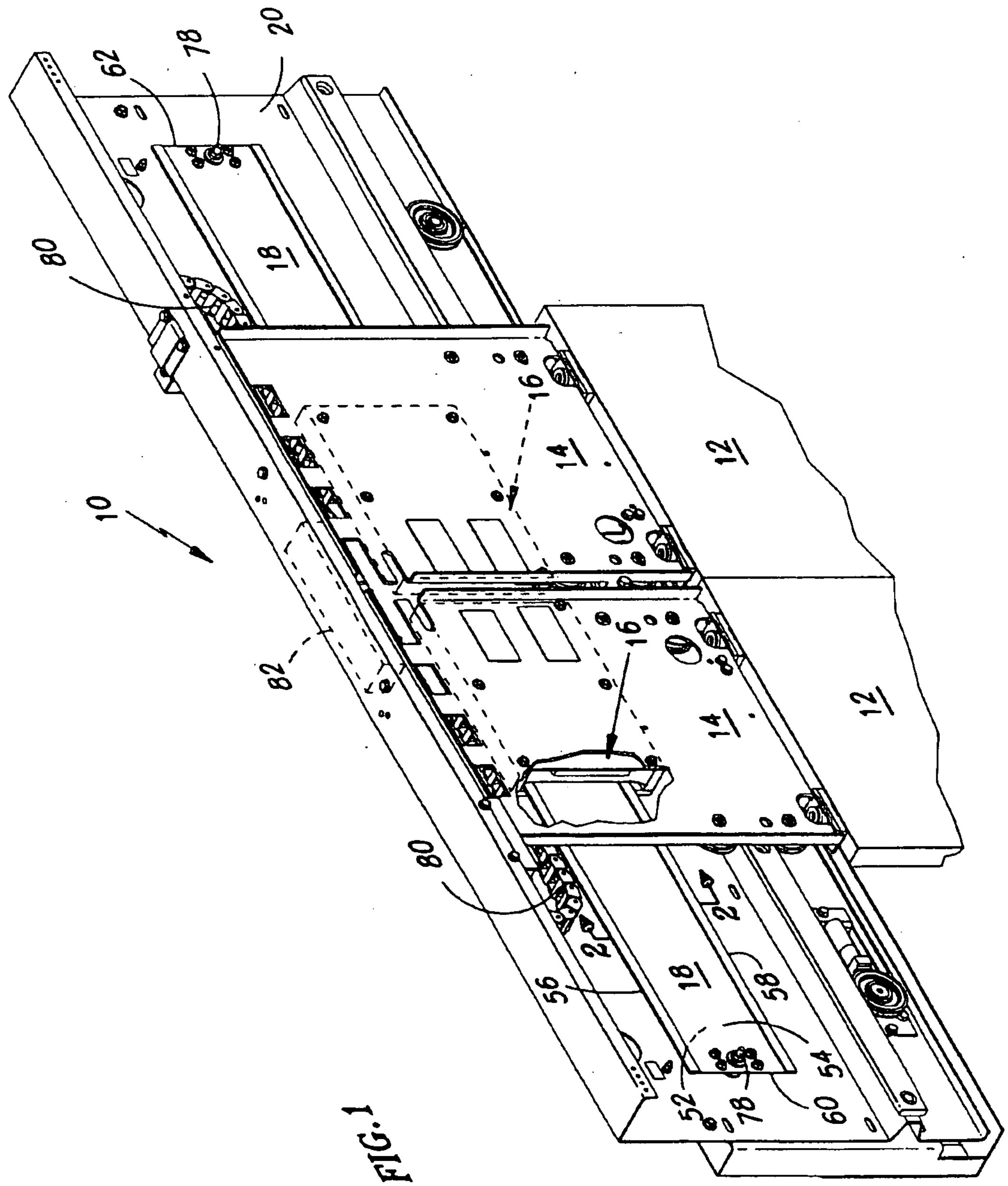
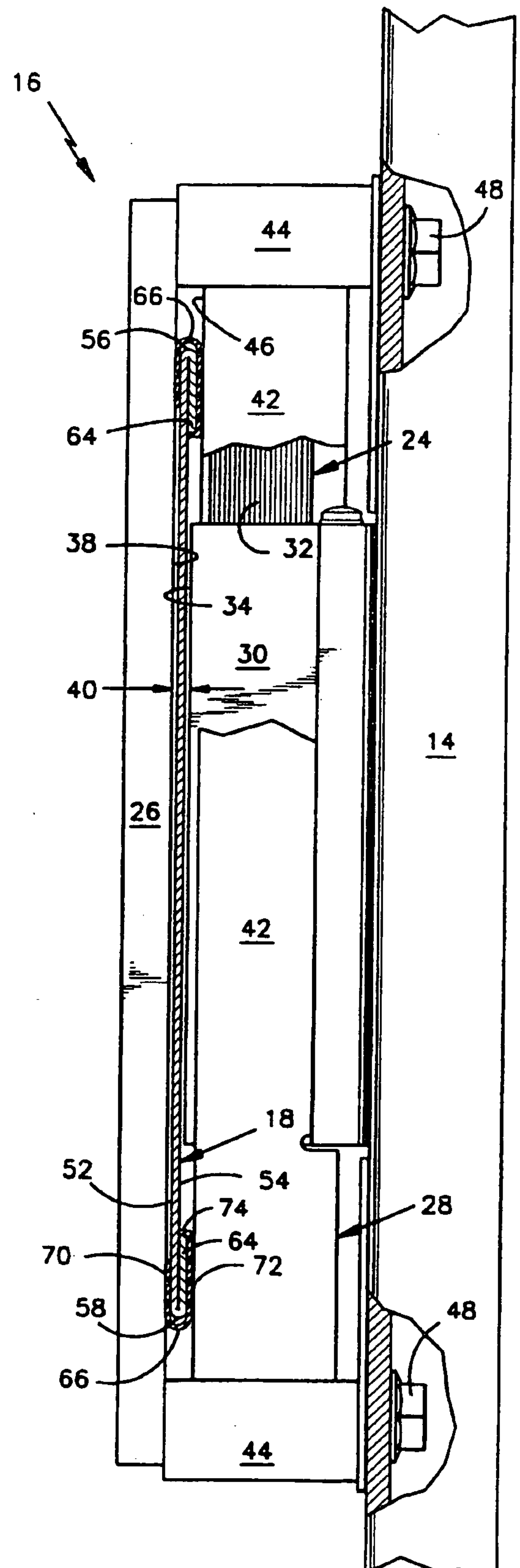


FIG. 1

FIG.2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Application Number
EP 97 30 8731

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X Y A	PATENT ABSTRACTS OF JAPAN vol. 016, no. 082 (M-1215), 27 February 1992 -& JP 03 264486 A (MITSUBISHI ELECTRIC CORP), 25 November 1991, * abstract *	1-3 5 4	B66B13/08 H02K41/02 E05F15/18
Y	DE 296 13 605 U (INVENTIO AG) * page 3, line 24 - page 4, line 2 *	5	
X,D	US 5 172 518 A (YOSHINO MITSUJI) * column 2, line 37 - line 57 *	1	
A	GB 1 406 316 A (CONZ ELEKTRIZITAETS GMBH) * page 2, line 43 - line 50 *	1-3	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	30 January 1998	Sozzi, R

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